Stochastic Streamflow Forecast Generation

stochastic:

adj. [Gk *stochastikos* proceeding by guesswork]

Containing a random variable; word used to describe a system that has in it an element of randomness.

Purpose of using synthetic streamflows instead of historical:

Reduce and more appropriately reflect uncertainty of future reservoir inflows and their effect on power marketing and reservoir operating decisions

Uses for Stochastic Flows

- Operations studies that determine inventory on probabilistic basis in support of marketing decisions

- Risk management-- studies that show the risk of operating the system to meet specific criteria

The Problem

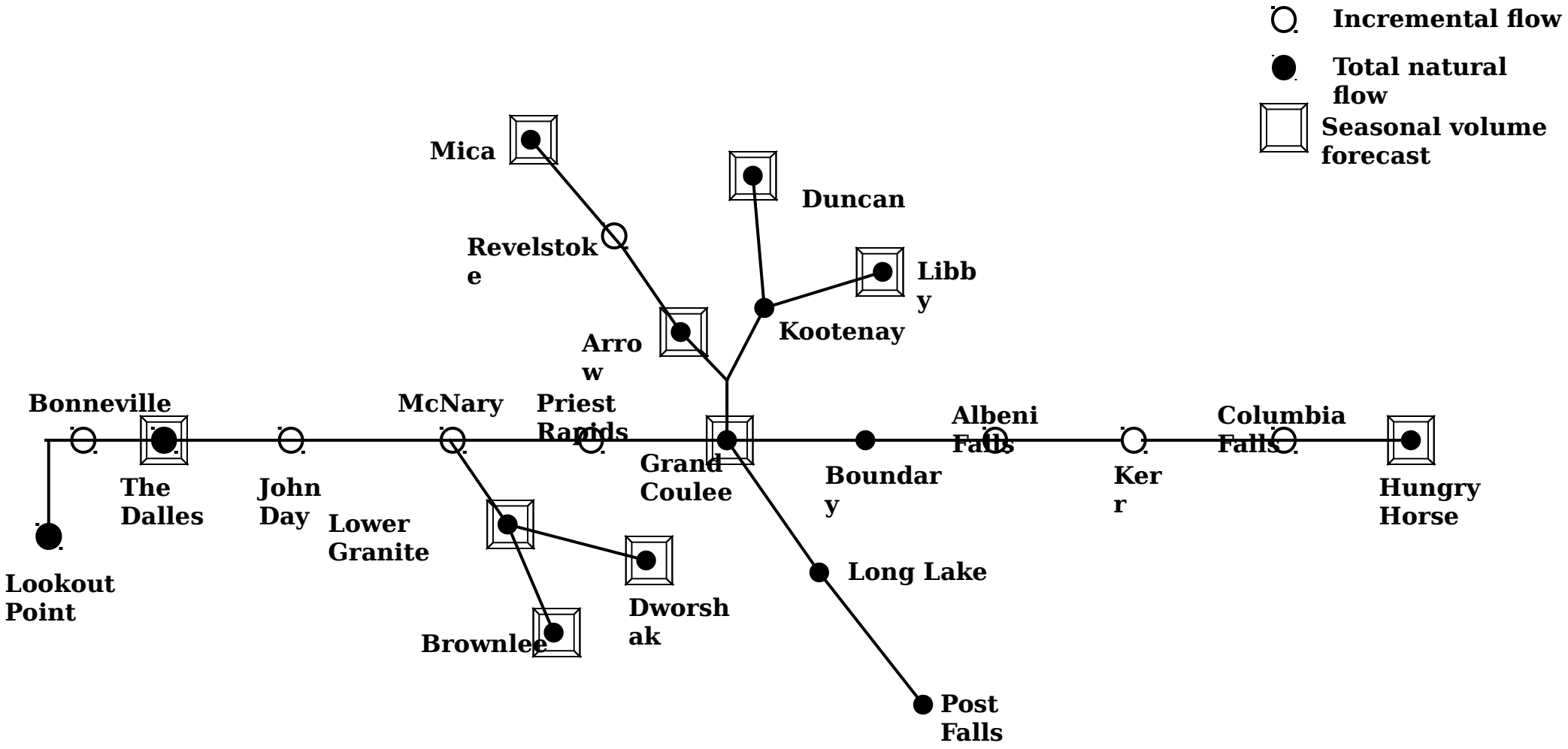
- Produce sequences of monthly streamflows at 23 sites for forecast horizon of up to 2 years

- Synthetic streamflows must behave statistically similar to historical values and be consistent with seasonal volume forecasts

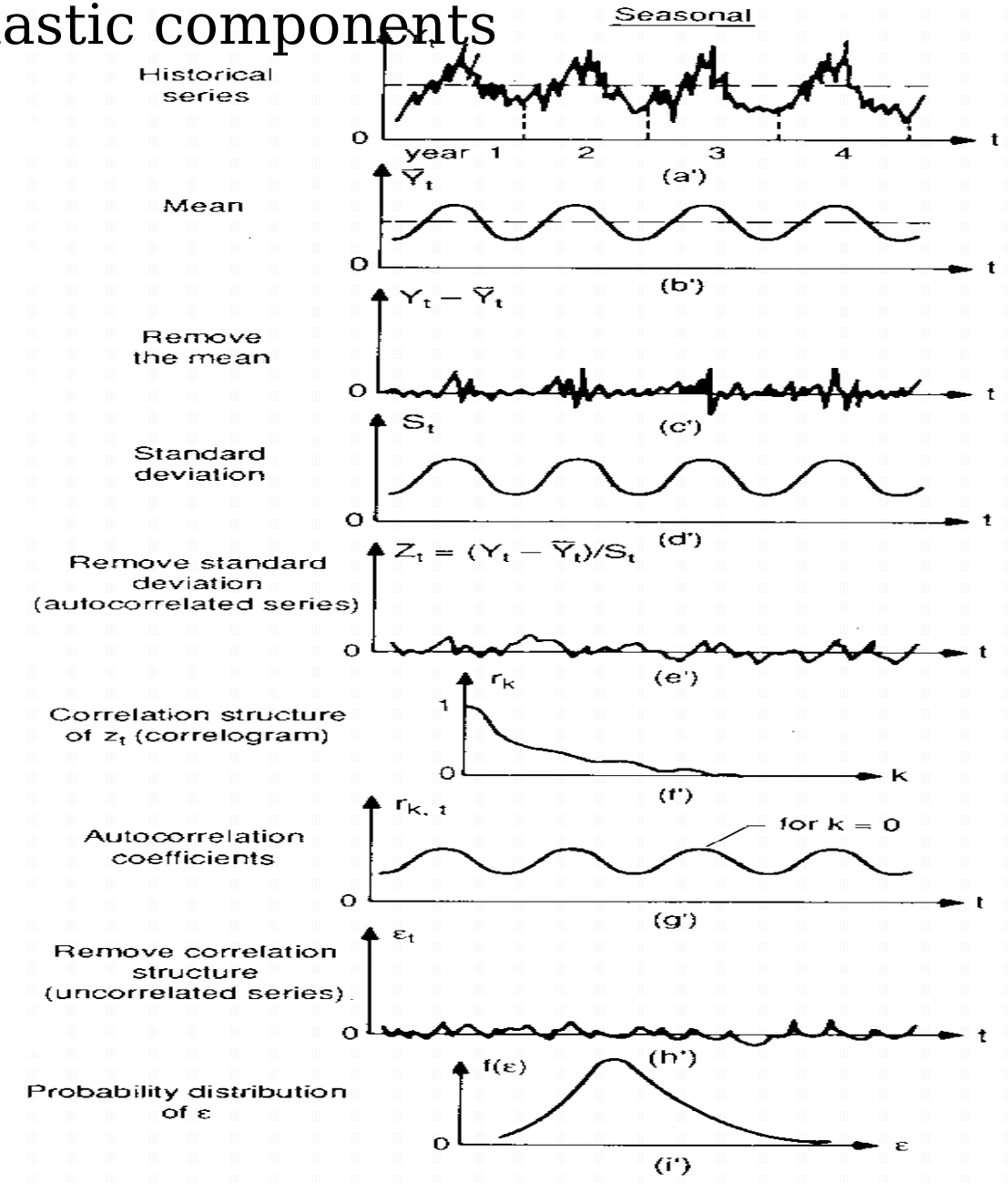
The Solution

- SAMS (Stochastic Analysis, Modeling, and Simulation) -- developed as coop effort between CSU and USBR
- BPA funded enhancements to the model including the capability to generate based on initial conditions
- forecasts conditioned on NWRFC final volume forecasts and antecedent flows

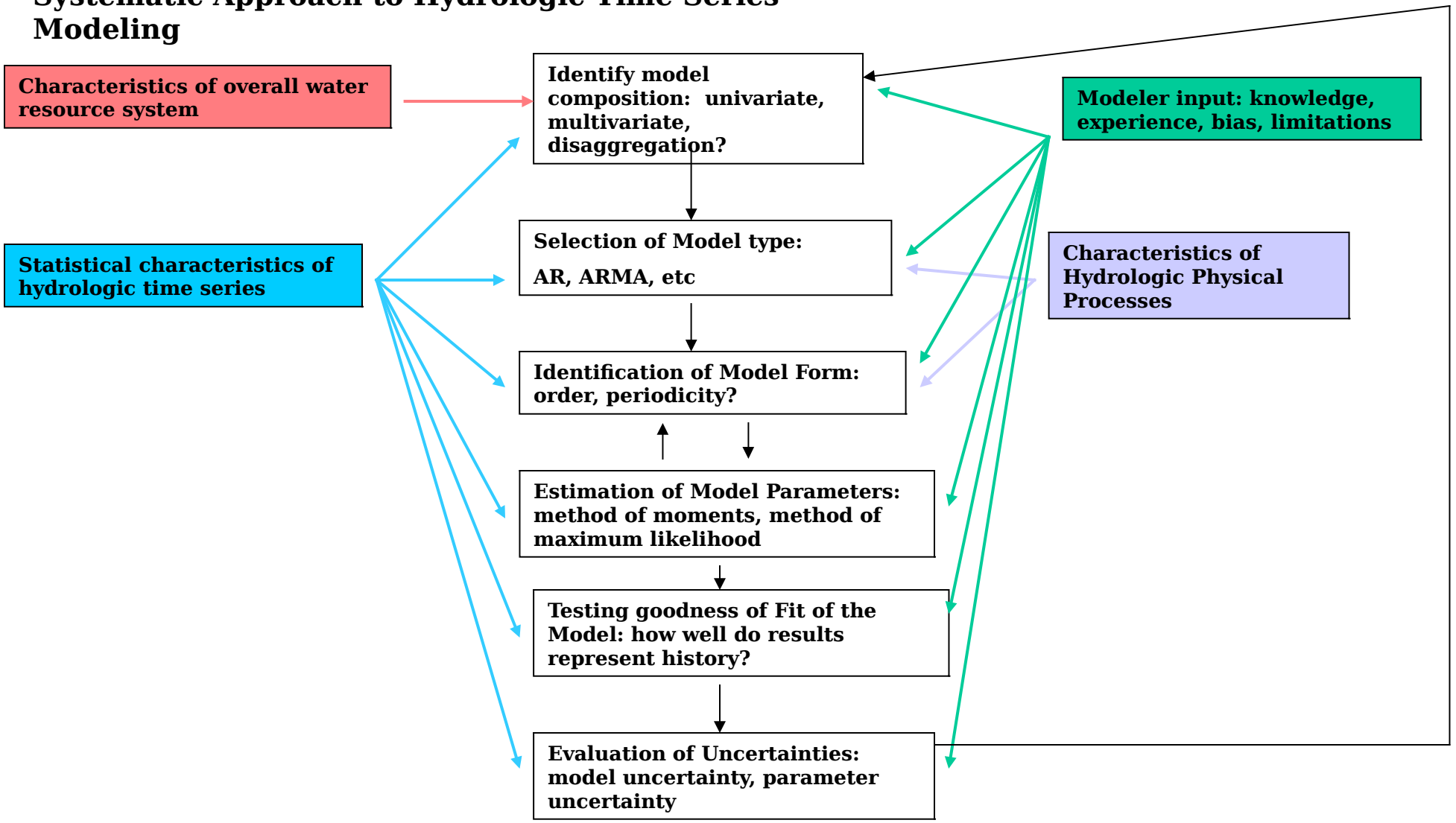
Configuration of Basin



Partitioning a time series into its various components -- deterministic and stochastic components

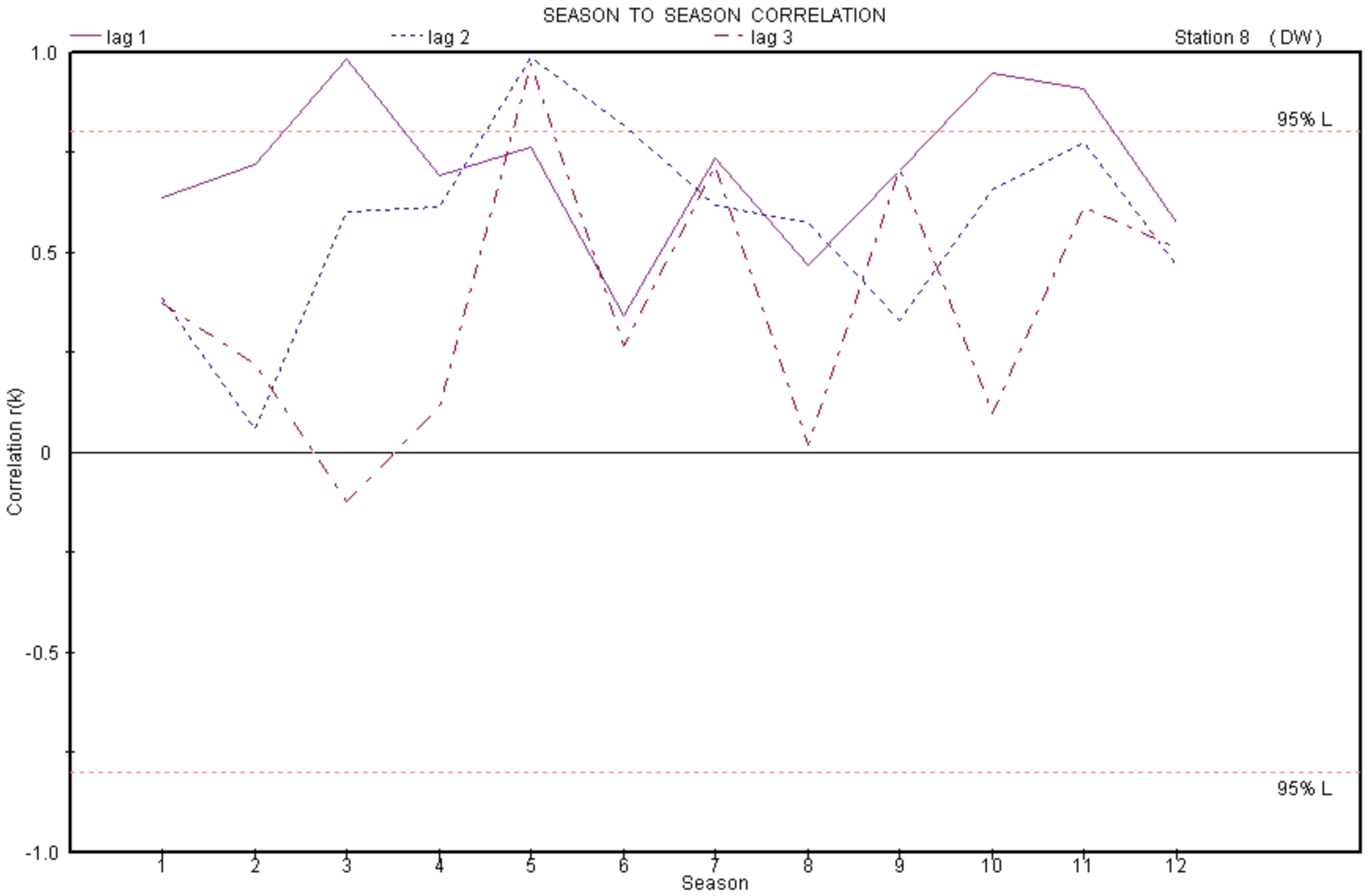


Systematic Approach to Hydrologic Time Series Modeling


Characteristics of overall water resource system
Identify model composition: univariate, multivariate, disaggregation?
Modeler input: knowledge, experience, bias, limitations
Statistical characteristics of hydrologic time series
Selection of Model type:
AR, ARMA, etc
Characteristics of Hydrologic Physical Processes
Identification of Model Form: order, periodicity?
Estimation of Model Parameters: method of moments, method of maximum likelihood
Testing goodness of Fit of the Model: how well do results represent history?
Evaluation of Uncertainties: model uncertainty, parameter uncertainty

- Stochastic models reproduce basic statistics and probability distributions of the historic data

- assumption that variable is normally distributed


SEASON TO SEASON CORRELATION
lag 1
lag 2
lag 3
Station 8 (DW)
1.0
0.5
0
-0.5
-1.0
95% L
95% L
Correlation r(k)
1
2
3
4
5
6
7
8
9
10
11
12
Season

Approach

- MPAR(3) used for 6 key sites
- Spatial disaggregation of seasonal data for other 17 sites--generation of subkey sites (and subsequent sites) dependent on generated values at key sites
- Used modified flows for 1929-1983 and Kuehl Moffitt synthetic seasonal volume forecasts

Autoregressive model univariate, stationary case

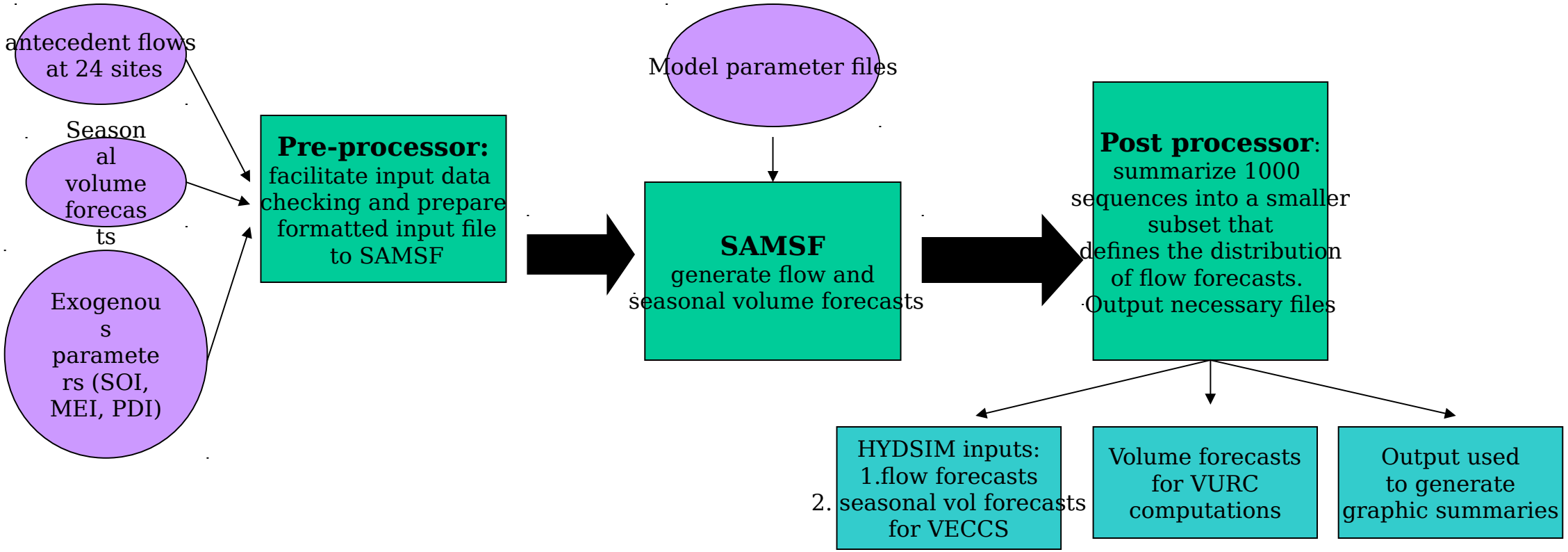
$$y_\tau = \mu + \sum_{j=1}^{p} \varphi_j \left(y_{\tau - j} - \mu\right) + \varepsilon_\tau$$

Multivariate case and periodic case more complicated--matrix form used

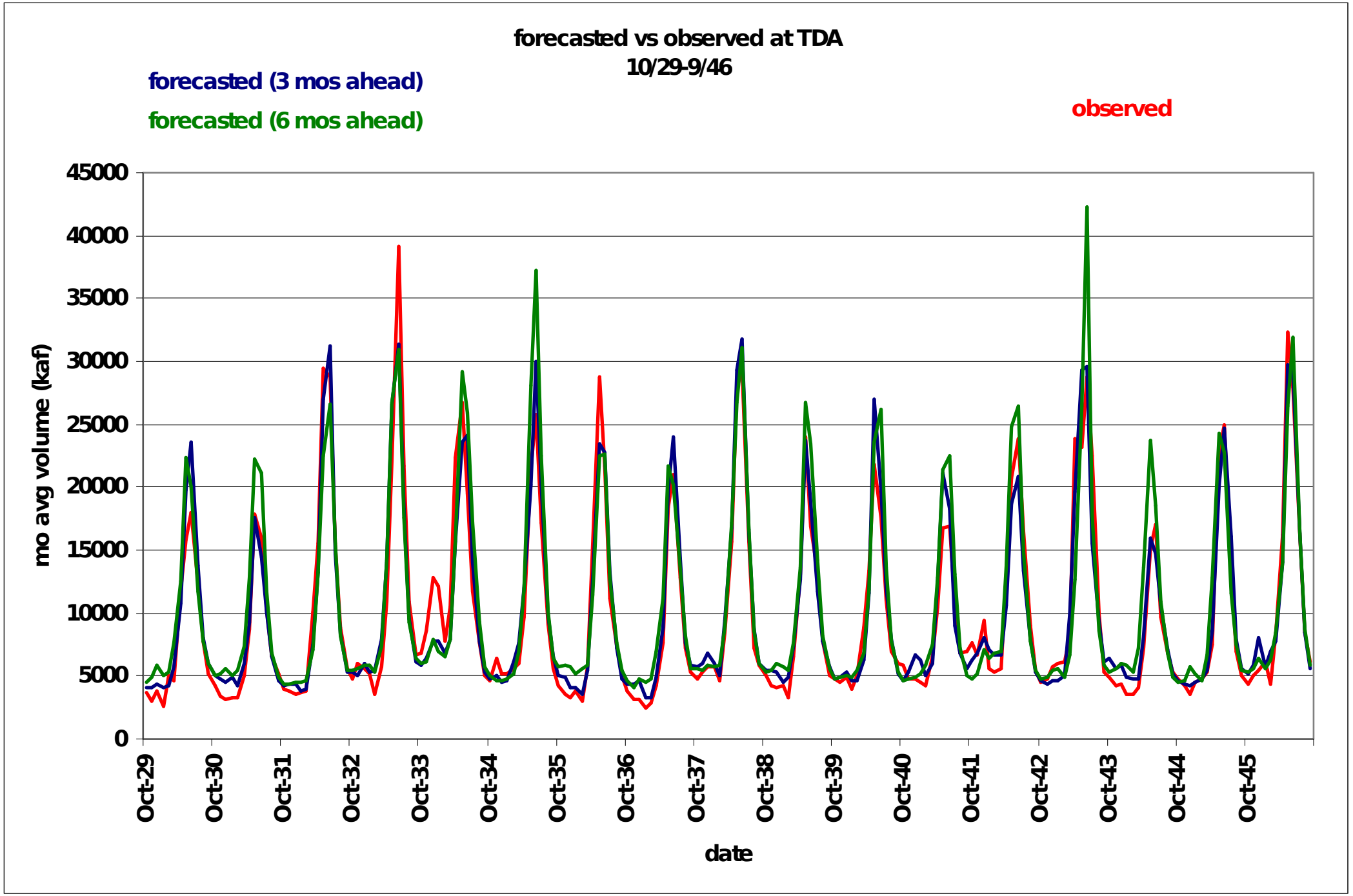
Dissagregation models

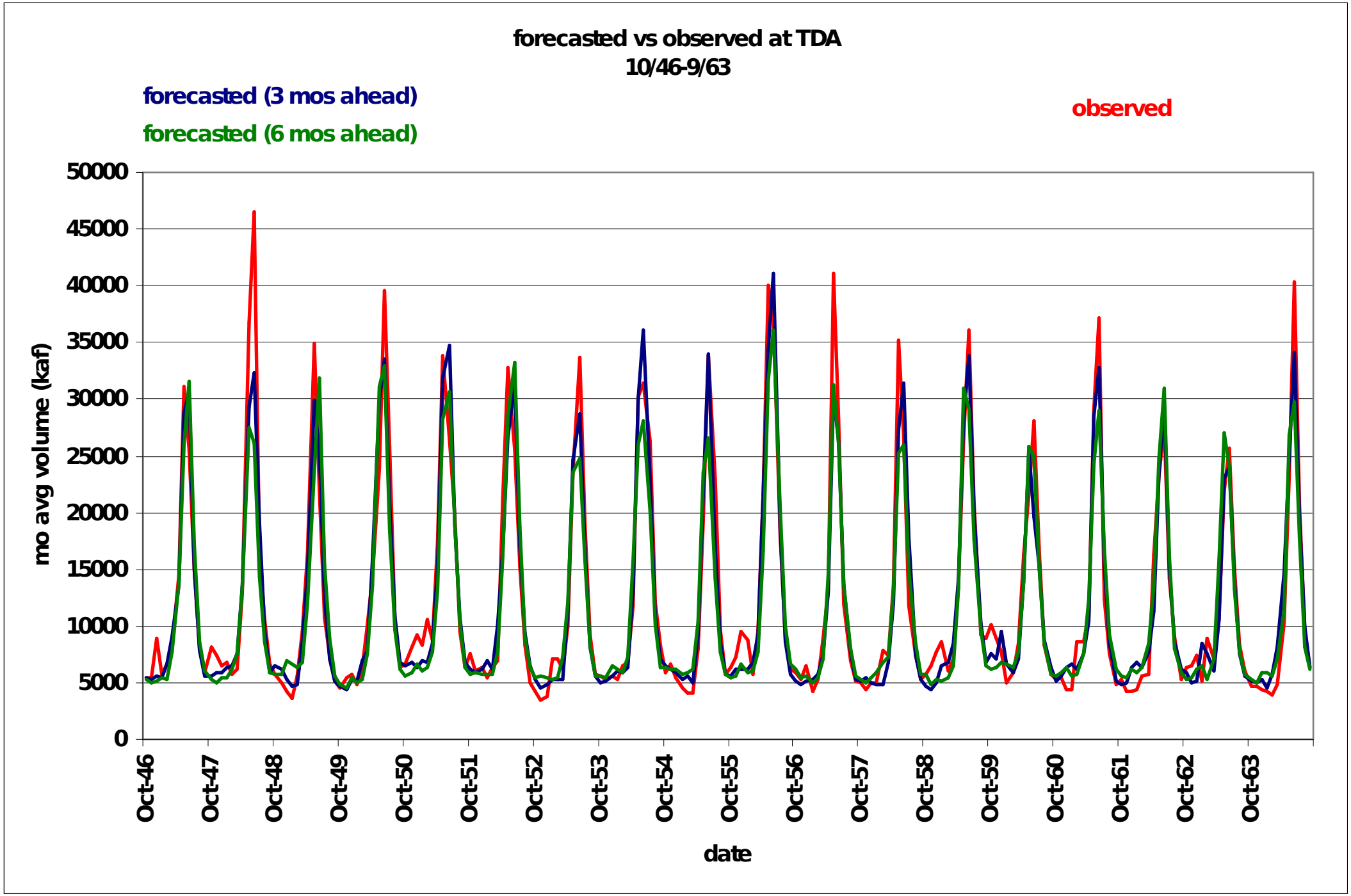
- Developed for reproducing statistics at more than one level of aggregation
- General Form: $Y = A X + B Z + C \varepsilon$

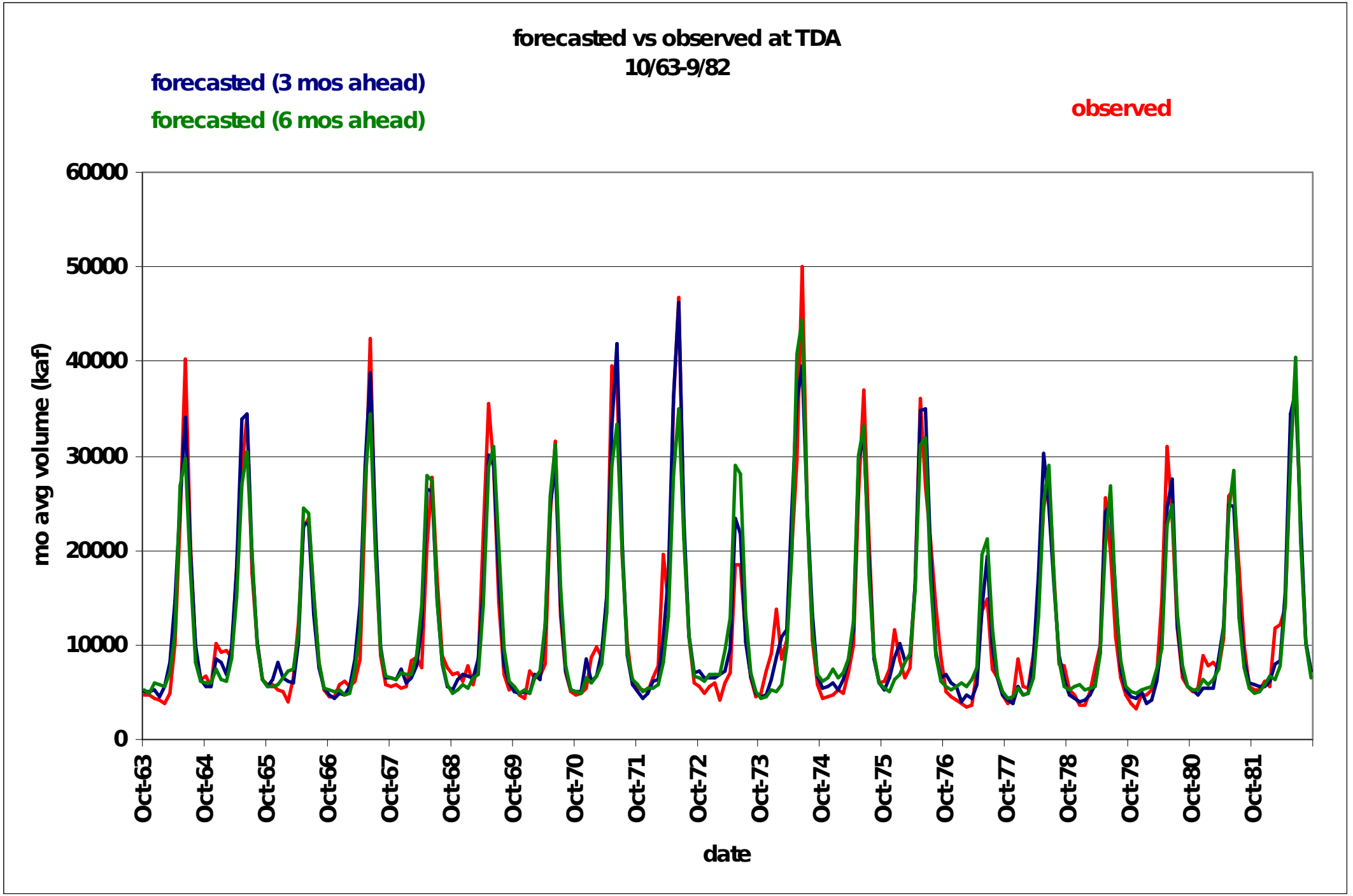
Stochastic Flow Forecast Generation Process

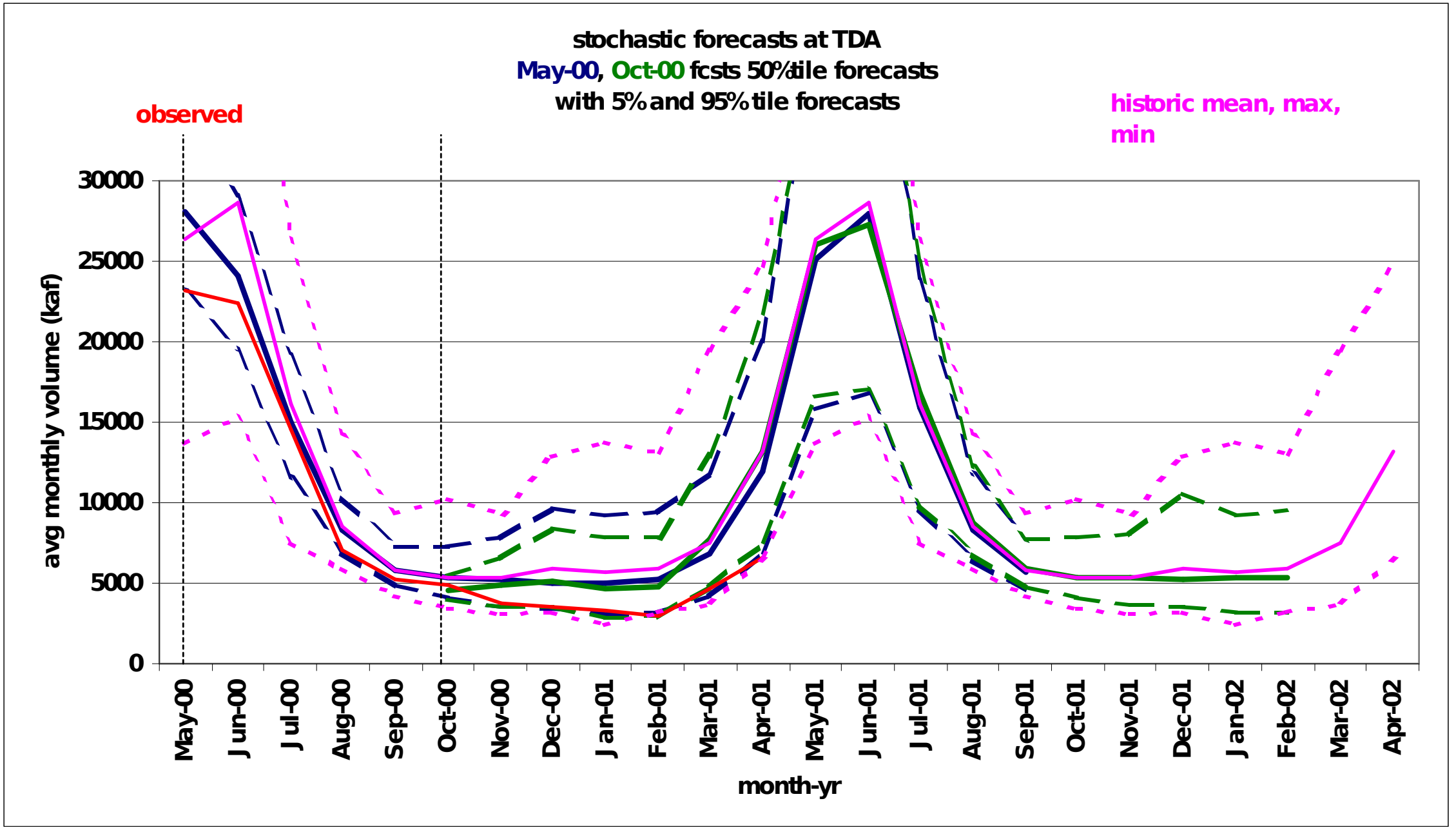

antecedent flows at 24 sites
Seasonal volume forecasts
Exogenous parameters (SOI, MEI, PDI)
Pre-processor: facilitate input data checking and prepare formatted input file to SAMSF
Model parameter files
SAMSF generate flow and seasonal volume forecasts
Post processor: summarize 1000 sequences into a smaller subset that defines the distribution of flow forecasts. Output necessary files
HYDSIM inputs: 1.flow forecasts 2. seasonal vol forecasts for VECCS
Volume forecasts for VURC computations
Output used to generate graphic summaries

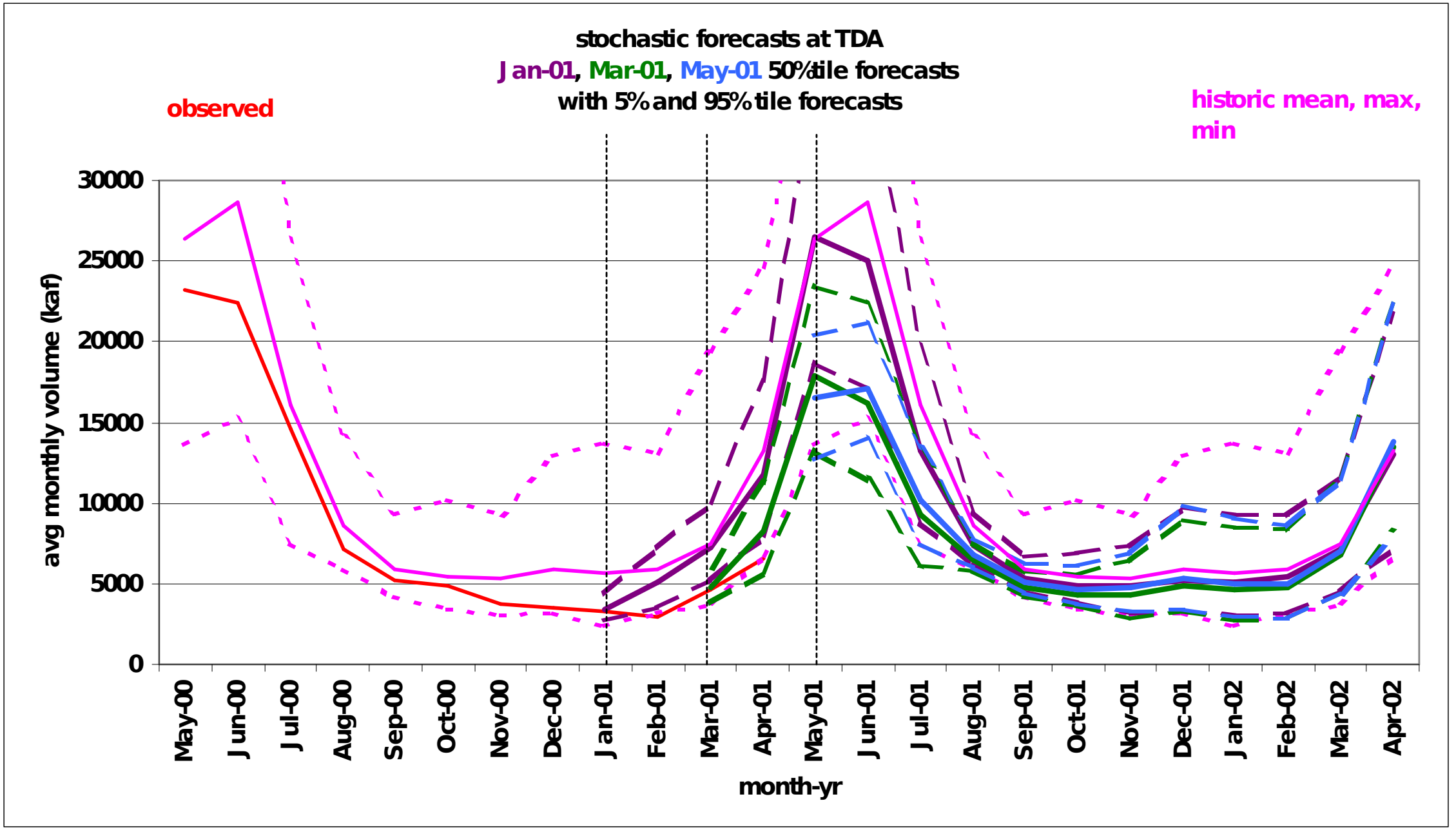
Results


forecasted vs observed at TDA
10/29-9/46
forecasted (3 mos ahead)
forecasted (6 mos ahead)
observed
mo avg volume (kaf)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Oct-29
Oct-30
Oct-31
Oct-32
Oct-33
Oct-34
Oct-35
Oct-36
Oct-37
Oct-38
Oct-39
Oct-40
Oct-41
Oct-42
Oct-43
Oct-44
Oct-45
date


forecasted vs observed at TDA
10/46-9/63
forecasted (3 mos ahead)
forecasted (6 mos ahead)
observed
mo avg volume (kaf)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Oct-46
Oct-47
Oct-48
Oct-49
Oct-50
Oct-51
Oct-52
Oct-53
Oct-54
Oct-55
Oct-56
Oct-57
Oct-58
Oct-59
Oct-60
Oct-61
Oct-62
Oct-63
date


forecasted vs observed at TDA
10/63-9/82
forecasted (3 mos ahead)
forecasted (6 mos ahead)
observed
mo avg volume (kaf)
60000
50000
40000
30000
20000
10000
0
Oct-63
Oct-64
Oct-65
Oct-66
Oct-67
Oct-68
Oct-69
Oct-70
Oct-71
Oct-72
Oct-73
Oct-74
Oct-75
Oct-76
Oct-77
Oct-78
Oct-79
Oct-80
Oct-81
date


stochastic forecasts at TDA
May-00, Oct-00 fcsts 50%tile forecasts
with 5% and 95%tile forecasts
observed
historic mean, max, min
avg monthly volume (kaf)
30000
25000
20000
15000
10000
5000
0
May-00
Jun-00
Jul-00
Aug-00
Sep-00
Oct-00
Nov-00
Dec-00
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
Jan-02
Feb-02
Mar-02
Apr-02
month-yr


stochastic forecasts at TDA
Jan-01, Mar-01, May-01 50%tile forecasts
with 5% and 95%tile forecasts
observed
historic mean, max, min
avg monthly volume (kaf)
30000
25000
20000
15000
10000
5000
0
May-00
Jun-00
Jul-00
Aug-00
Sep-00
Oct-00
Nov-00
Dec-00
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
Jan-02
Feb-02
Mar-02
Apr-02
month-yr

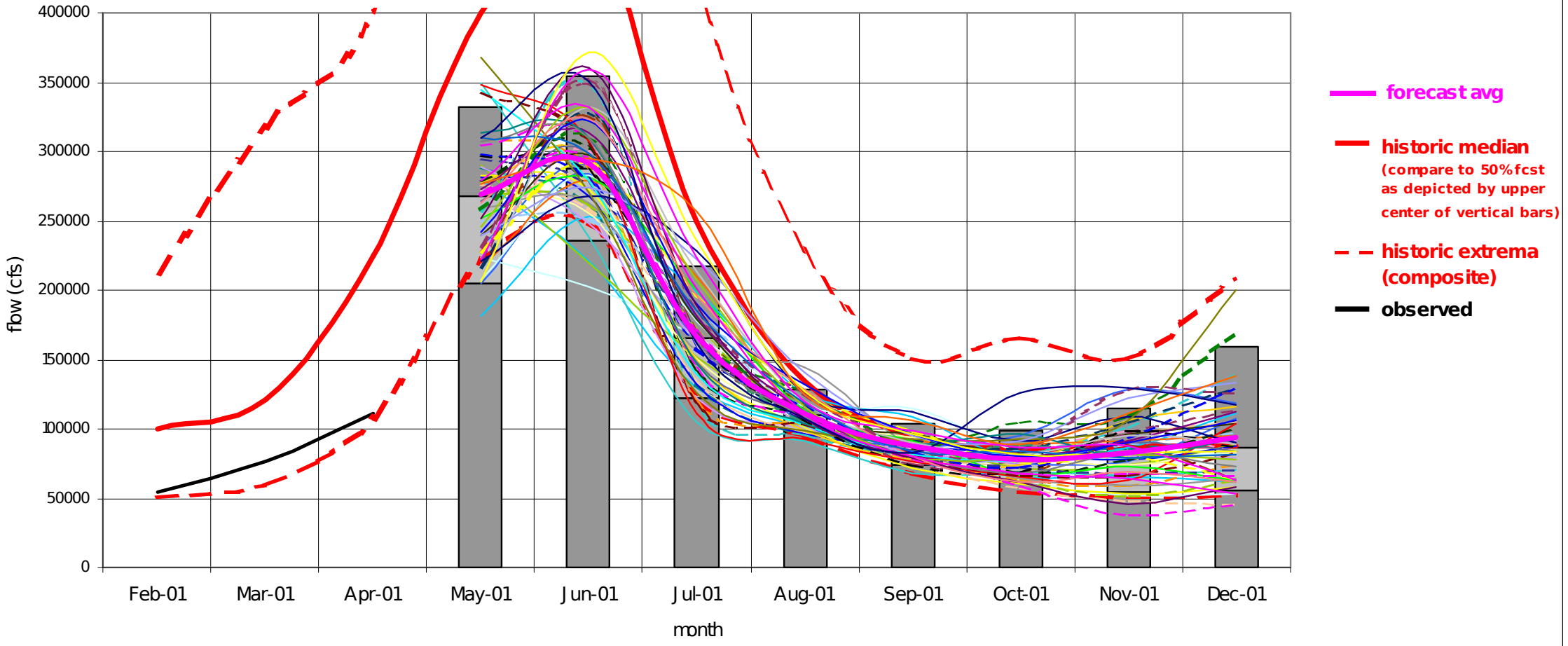
study date: 5/23/0

monthly stochastic flow fcsts, cond'd on obs flows thru Apr 30;
May FF vol fcst; char'd by 60 uniform quantiles (using May-Sep vol at TDA);
vert bars are 5%, 50%, 95%-tiles of fcst dist (using mo'ly vol at site)

based on FF May TDA jan-jul fcst=56.5 MAF

TDA(365)

fcst period: may 2001 - apr 2002



Future opportunities

- gain experience using stochastic forecasts
- disaggregate into daily/weekly flows
- produce forecasts at more sites
- use of exogenous variables
- condition on new NWRFC volume forecasts
- compare to ESP